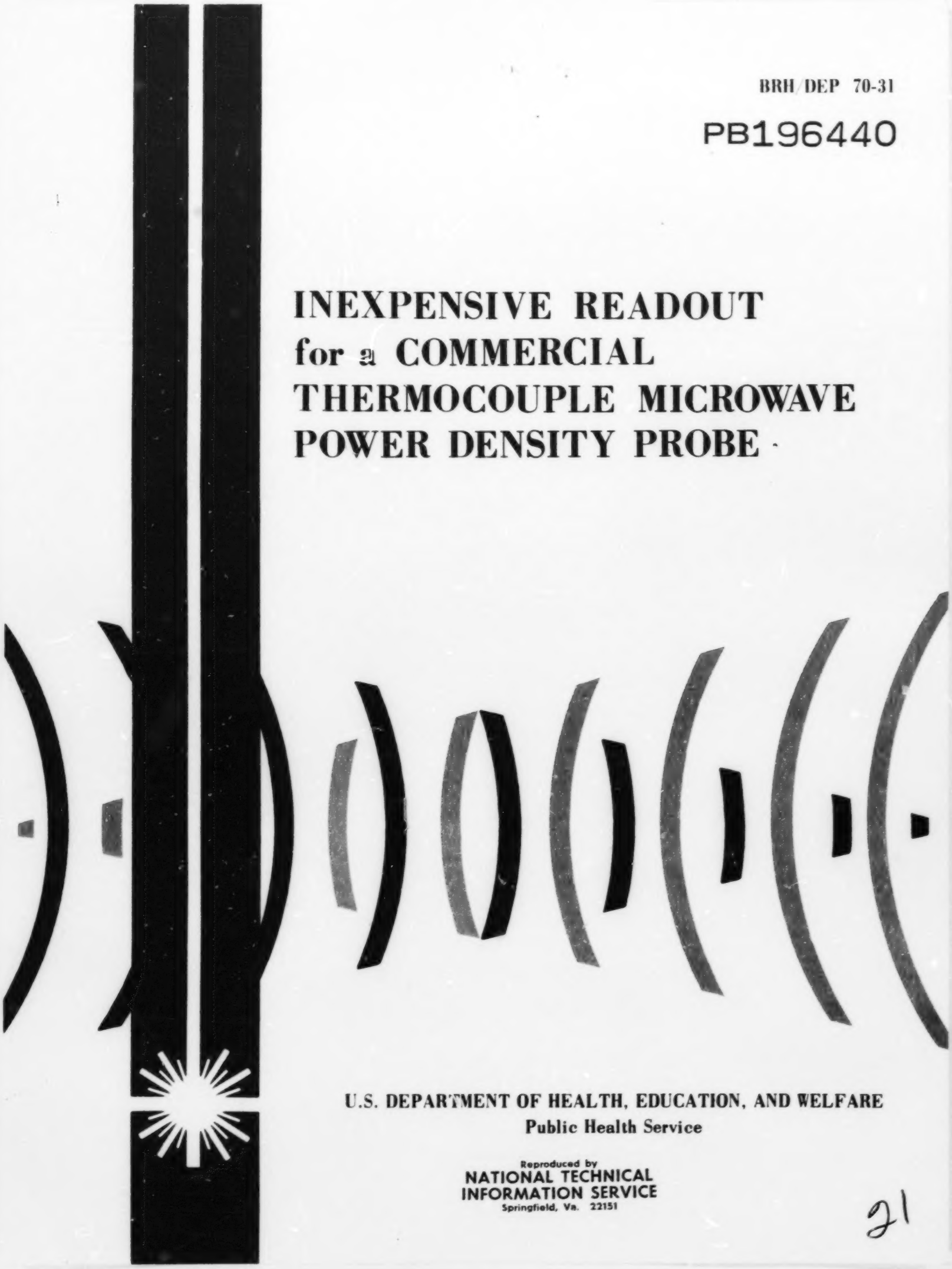
BRH/DEP 70-31

PB196440

INEXPENSIVE READOUT for a COMMERCIAL THERMOCOUPLE MICROWAVE POWER DENSITY PROBE



U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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DIVISION OF ELECTRONIC PRODUCTS

List of Publications

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BRH/DEP 70-31

INEXPENSIVE READOUT for a COMMERCIAL THERMOCOUPLE MICROWAVE POWER DENSITY PROBE

Robert L. Cloke
Radiation Measurements and Calibration Branch
Division of Electronic Products

December 1970

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Bureau of Radiological Health
Rockville, Maryland 20852

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FOREWORD

The Bureau of Radiological Health, formerly the National Center for Radiological Health, continues to carry out a national program designed to reduce the exposure of man to hazardous ionizing and nonionizing radiation.

Within the Bureau, the Division of Electronic Products (1) develops and administers performance standards for radiation emissions from electronic products, (2) studies and evaluates emissions of and conditions of exposure to electronic product radiation and intense magnetic fields, (3) conducts or supports research, training, development, and inspections to control and minimize such hazards, and (4) tests and evaluates the effectiveness of procedures and techniques for minimizing such exposures.

The Bureau publishes its findings in Radiological Health Data and Reports (a monthly publication), Public Health Service numbered reports, appropriate scientific journals, and technical report series for the Bureau's divisions, offices, and laboratories.

The technical reports of the Division of Electronic Products (DEP) allow comprehensive and rapid publishing of the results of intramural and contractor projects. The reports are distributed to State and local radiological health program personnel, Bureau technical staff, Bureau advisory committee members, university radiation safety officers, libraries and information services, industry, hospitals, laboratories, schools, the press, and other interested individuals. These reports are also included in the collections of the Library of Congress and the National Technical Information Service.

I encourage the readers of these reports to inform the Bureau of any omissions or errors. Your additional comments or requests for further information are also solicited.

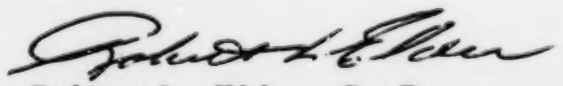
John C. Villforth
Director
Bureau of Radiological Health

PREFACE

The development of instrumentation for measuring radiation exposure from electronic products is a major responsibility of the Division of Electronic Products, Bureau of Radiological Health. When adequate or suitable instruments for a particular application are not available, it is the responsibility of the Division's Radiation Measurements and Calibration Branch to develop them. This report describes the results of an effort to design simple and inexpensive instruments that could be used by technicians to detect radiation leakage from microwave ovens.

The device described in this report was designed to be constructed by electronic technicians without specialized radiation measurement instrumentation experience. The instrument has all of the necessary features of the Narda 8100, but may be built for a fraction of the cost. The circuits can be built from commonly available, low-cost components, and calibration in a microwave field is unnecessary since the probe which is used is calibrated at the factory.

Construction and use of the instrument described herein will allow groups which have limited budgets to accurately measure microwave oven leakage.



Robert L. Elder, Sc.D.
Director
Division of Electronic Products

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ABSTRACT

This paper describes an inexpensive, easy-to-build readout circuit which can be used with the Narda 8122 thermocouple microwave power density probe. The instrument is capable of reading full-scale power densities of 10 mW/cm^2 and 100 mW/cm^2 at frequencies of 915 MHz and 2450 MHz, and includes all of the necessary features of the Narda 8100 system.

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INEXPENSIVE READOUT FOR A COMMERCIAL THERMOCOUPLE MICROWAVE POWER DENSITY PROBE

1. INTRODUCTION

The Narda 8100 Microwave survey instrument has proven to be a useful instrument for the survey of leakage from microwave ovens. Much of this success may be attributed to the design of the thin-film thermocouple detector probe. The probe is easy to use, equally sensitive to all polarizations, and has minimal interaction with the field which it measures. One drawback of the complete 8100 system is cost. Many organizations which would like to measure microwave leakage are unable to afford the complete Narda 8100 system.

Much of the cost of the Narda 8100 system is the relatively expensive 8110 meter and the requirement for two probes: one to measure large (greater than 20 mW/cm^2) leakages, and another to easily measure small leakages. Since the probes sold by Narda are calibrated to have a specific transfer characteristic, i.e., a specific ratio of output voltage to input power density, to ensure interchangeability between meters, an inexpensive meter may be designed to replace the elaborate 8110 meter. At the same time, by making the gain of the amplifier in the inexpensive meter greater than that of the 8110, the 8122 (red) probe (which was originally intended to measure 0-20 and 0-200 mW/cm^2) may be used to measure the more convenient ranges of 0-10 and 0-100 mW/cm^2.

The Division of Electronic Products has developed a metering system for use with one of the Narda probes. This meter can be constructed by technicians without specialized training for less than $50.00 (exclusive of the probe). The parts are readily available from local electronics dealers, except as noted in the parts list.

2. DESCRIPTION OF METER

Figure 1 shows the schematic diagram of the inexpensive meter. An integrated-circuit operational amplifier provides voltage amplification required to operate the meter movement.

Although the circuit would normally require very little care in construction for proper operation, this circuit will be operating in relatively intense electromagnetic field and therefore requires some rather strict, although not difficult, construction techniques. Complete shielding and bypassing of all semiconductor components is necessary to prevent pickup and rectification of the electromagnetic field, which would cause d. c. currents to flow and interfere with the minute currents at the input of the operational amplifier.

The shielding and bypassing is accomplished by enclosing the operational amplifier, meter protecting diodes, and associated components (as shown on the circuit diagram, figure 1) in a solder-sealed metal can (such as an all-metal frozen juice can or tomato paste can) and bypassing all leads entering or leaving the can with ceramic coaxial capacitors. This form of construction, while quite easy for a minimally-experienced technician, provides a very interference-free enclosure for the sensitive parts of the circuit.

The circuit operates as follows: The voltage which is developed by the thermocouple in the Narda 8122 probe is applied to the noninverting input of the operational amplifier (pin 3). Resistor R_2 provides a small offset current to give a full-upscale reading in the event that the thermocouple becomes open-circuited or unplugged. This serves as a built-in probe test circuit which operates at all times. The gain of the operational amplifier is determined by the network composed of R_1, R_6 through R_9, S_1 and S_2, and the feedback resistors contained in the probe. These probe resistors are set at the Narda factory as probe calibrations for each frequency.

The network R_6 through R_9 is designed to provide a gain change of ten when S_2 is thrown, independent of the value of the external feedback resistor, thus providing two ranges of sensitivity differing by a factor of ten. S_1 chooses the proper external resistor for the frequency range used.

Resistors R_3, R_{10}, and R_{11} are used to adjust for a zero meter reading with no microwave energy incident on the probe. Two variable resistors are used to allow very easy zero adjustment. The fine zero adjustment, R_{11}, could be eliminated, but zero adjustment is then more difficult.

Components C_1, C_2, and R_4 provide frequency compensation of the operational amplifier to assure stable operation under all feedback conditions. R_5, D_1, and D_2 form a limiting circuit with a threshold of about $\pm$ 1/2 volt to ensure against overloading the meter movement.

R_{12} adjusts the sensitivity of the circuit, while S_4 and R_{13} allow the operator to check the battery voltage. When the switch is placed in the "Battery Check" position, the meter will read the percentage of full battery voltage. The batteries should be replaced when they have less than 80 percent voltage or when there is excessive zero drift of the meter.

3. CONSTRUCTION OF METER

The meter may be built in a box measuring 5 inches by 7 inches by 2 inches. Figure 2 shows how the shielded can is assembled. The can should be cut down to about 1 or 1-1/2 inches in height and should be about 2 inches in diameter. It must be made of tin-plated steel, not cardboard or aluminum (test with a magnet if in doubt), and all paint or clear enamel must be removed wherever solder joints will be. Six feedthrough capacitors are spaced around half of the circumference of the can and soldered onto the can to ensure perfect contact.

Figure 4 is a pictorial wiring diagram. All wires should be soldered to the points shown, but the wire length should be kept as short as possible (they are longer than necessary in the drawing for clarity).

After the meter is assembled, it should be checked out, calibrated, and final assembly completed as follows:

(1) Recheck the wiring carefully and completely, particularly inside the can, using figures 1, 2, and 4 as guides.

(2) Temporarily ground the tie-point mounting foot to the metal case.

(3) Check the wiring of switch S_1 as follows:

(a) Clip one lead of an ohmmeter to the center contact of S_1.

(b) Clip the other ohmmeter lead to pin 1 of J_1.

(c) The ohmmeter should read 0 ohms when S_1 is in the 2450 MHz position and ∞ ohms when S_1 is in the 915 MHz position.

(d) Change the ohmmeter lead which was on pin 1 of J_1 to pin 5 of J_1.

(e) The ohmmeter should read 0 ohms when S_1 is in the 915 MHz position and ∞ ohms when S_1 is in the 2450 MHz position.

(4) Assemble the test circuit as shown in figure 3 and attach it to the input connector, J_1. Do not apply voltage to V-INPUT.

(5) Turn on the power switch. Using the course and fine zero adjustments, set the meter pointer to read zero. Again, no voltage should be applied to V-INPUT.

(6) Check S_4 as follows:

(a) In the BATT. TEST position, which should be the spring-return position, the meter should read the relative battery voltage, and the zero adjustments should have little effect.

(b) In the OPERATE position, the normal position for this switch, the meter should be easy to adjust to zero when S_1 is in the 2450 MHz position and S_2 is in either position.

(7) Apply 0.1 volt to the V-INPUT terminals of figure 3. The meter should read approximately 1/3 of full scale on the 0-10 mW/cm^2 position of S_2 and less than 1/10 of full scale on the 0-100 mW/cm^2 scale. The voltage necessary to make these tests and calibrations may be obtained from a well-filtered variable d.c. power supply or from a 1 Kohm to 10 Kohm potentiometer connected across a fixed power supply or battery. Monitor V-INPUT with a voltmeter which is known to be precise.

(8) Setting V-INPUT to exactly zero and S_2 to 0-10 mW/cm^2, precisely zero the meter with the fine zero control. Now increase V-INPUT to 0.325 volts, and adjust R_{12} for a 10 mW/cm^2 (full scale) reading. Reset V-INPUT to zero and check to be sure that the meter is still zeroed. If it is not, this calibration procedure should be repeated.

An alternate method of calibration is to use the above procedure, but use the 0-100 mW/cm^2 scale and 3.25 volts at V-INPUT. The two procedures should give comparable results, within the tolerance of resistors R_6 through R_9.

The meter may be calibrated on either scale, but should be checked on the other scale to make sure that the scales are different in sensitivity by a factor of 10.

(9) After all components are soldered in place and it has been determined that the circuit works and that the lid does not short-circuit any internal wiring, the can lid may be soldered on. The best way to accomplish this is as follows:

(a) Tack one point on the edge of the lid to one point on the edge of the can.

(b) Bend the lid down into the can so that the lid sits about 1/16-inch into the can. Tack solder the lid at this position at a point on the opposite side of the can from the first tack solder joint.

(c) Unsolder the original tack joint and press this side of the lid inward so that the complete lid sits 1/16-inch into the can.

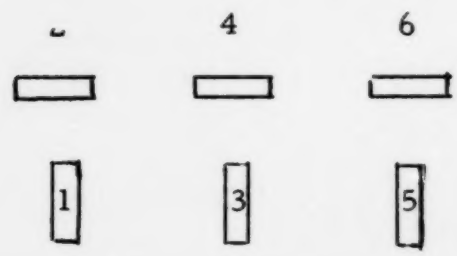
(d) Resolder the first tack joint and then proceed to solder the can shut beginning at the second tack joint. Try to make as tight a seal as possible, although an air-tight seal is not necessary. The tin-plated can should be very easy to solder. If not, the can probably is not clean of paint or the can is not tin plated. In either case, the can should be cleaned or replaced before attempting to solder the lid on.

(10) Recheck the meter after soldering the lid shut.

(11) The unit is now complete. Remove the test circuit and plug in a Narda 8122 probe. It should be possible to zero the meter under any combination of positions of switches S_1 and S_2. Use a 2-inch spacer on the Narda probe for 2450 MHz and the Narda antenna-cone, Model 8130, for 915 MHz.

The ultimate accuracy of the instrument is determined by the calibration accuracy of the probe ($\pm$ 1dB). The response time of the meter to a step input of microwave energy has been measured in the laboratories of the Division of Electronic Products and is 1.3 seconds.

4. PARTS LIST

	Description
B_1, B_2:	9-volt transistor radio battery, Burgess 2U6 or equivalent
C_1:	0.005 µf, Disc, Ceramic, Min, 25, WVDC (Min)
C_2:	200 pf, Disc, Ceramic, Min, 25, WVDC (Min)
C_3, C_4:	0.001 µf, Disc, Ceramic, Min, 25, WVDC (Min)
C_B:	Six Centralab FT-1000 or MFT-1000 feed-through bypass capacitors or equivalent
D_1, D_2:	1N629 Silicon diode
IC_1 µA709C:	Operational amplifier: Fairchild U5B7709393 T.I. SN72709L Motorola MC 1709 CG
J_1:	Elco "Varicon" connector #01-1106-106 Base Diagram (as viewed from rear) 
M_1:	0-100 µA meter (printed scale may be altered to read 0-10 and 0-100 mW/cm^2 if desired)

PARTS LIST (Continued)

R_1:	200 ohms, 1% or 5% 1/4 w (Min)
R_2:	2.7 Mohms, 10% 1/4 w (Min)
R_3:	470 Kohms, 10% 1/4 w (Min)
R_4:	1.5 Kohms, 10% 1/4 w (Min)
R_5:	1.0 Kohms, 10% 1/4 w (Min)
R_6:	1.5 Kohms, 1% or 5% 1/4 w (Min)
R_7:	91 ohms, 1% or 5% 1/4 w (Min)
R_8:	82 ohms, 1% or 5% 1/4 w (Min)
R_9:	10 ohms, 1% or 5% 1/4 w (Min)
R_{10}:	5 Kohms, variable 1/2 w linear taper
R_{11}:	100 Kohms, variable 1/2 w linear taper
R_{12}:	1.5 Kohms, trimmer 1/4 w (Min)
R_{13}:	180 Kohms, 1% or 5% 1/4 w (Min)
R_{14}:	100 Kohms, 1% or 5% 1/4 w (Min)
R_{15}:	200 ohms, 1% or 5% 1/4 w (Min)
R_{16}:	200 ohms, 1% or 5% 1/4 w (Min)
S_1, S_2:	SPDT toggle switch
S_3:	DPDT toggle switch
S_4:	DPDT spring return toggle or rotary switch

PARTS LIST (Continued)

Case:	5"x7"x2" (minimum size) box or chassis with bottom plate

Miscellaneous terminal strips as indicated on pictorial

All of these parts are available from the large electronics mail order houses with the exception of J_1, which is available from: Pyttronic Industries, Inc., Stump Road, Montgomeryville, Pa. 18936, telephone: (215) 643-2850.

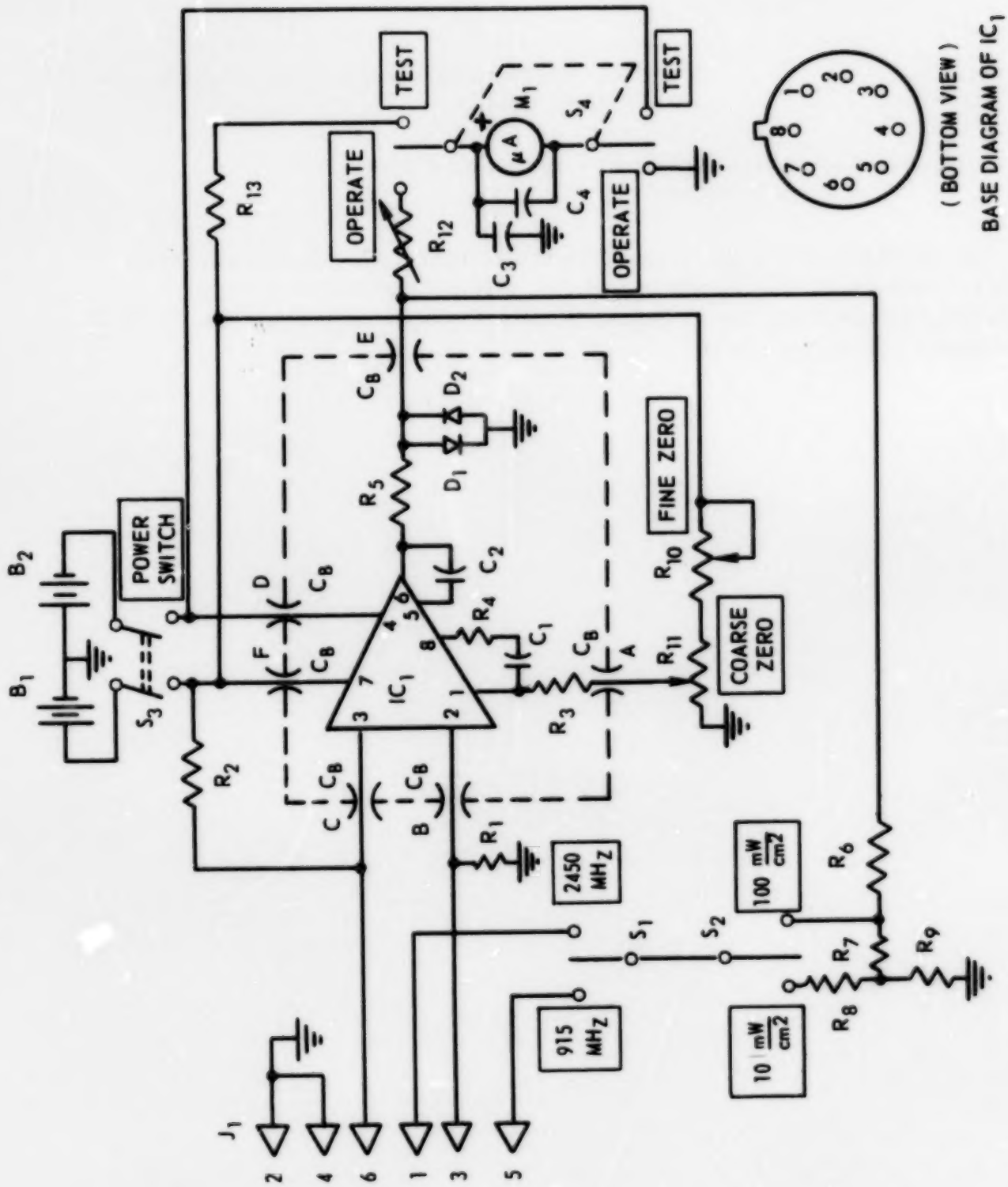


Figure 1 Schematic diagram of inexpensive readout for Narda 8122 probe

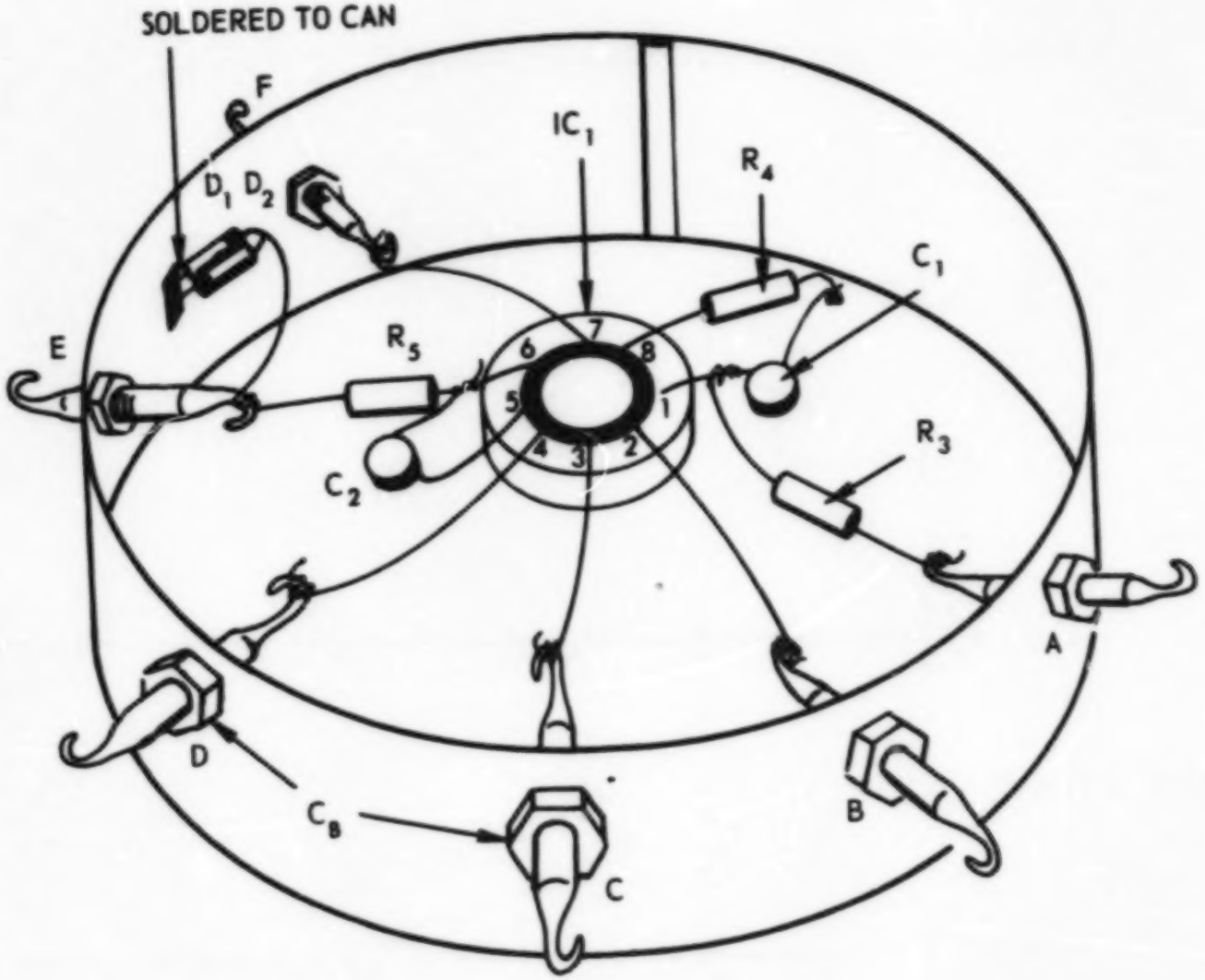


Figure 2 Pictorial drawing of the tin-can shield.

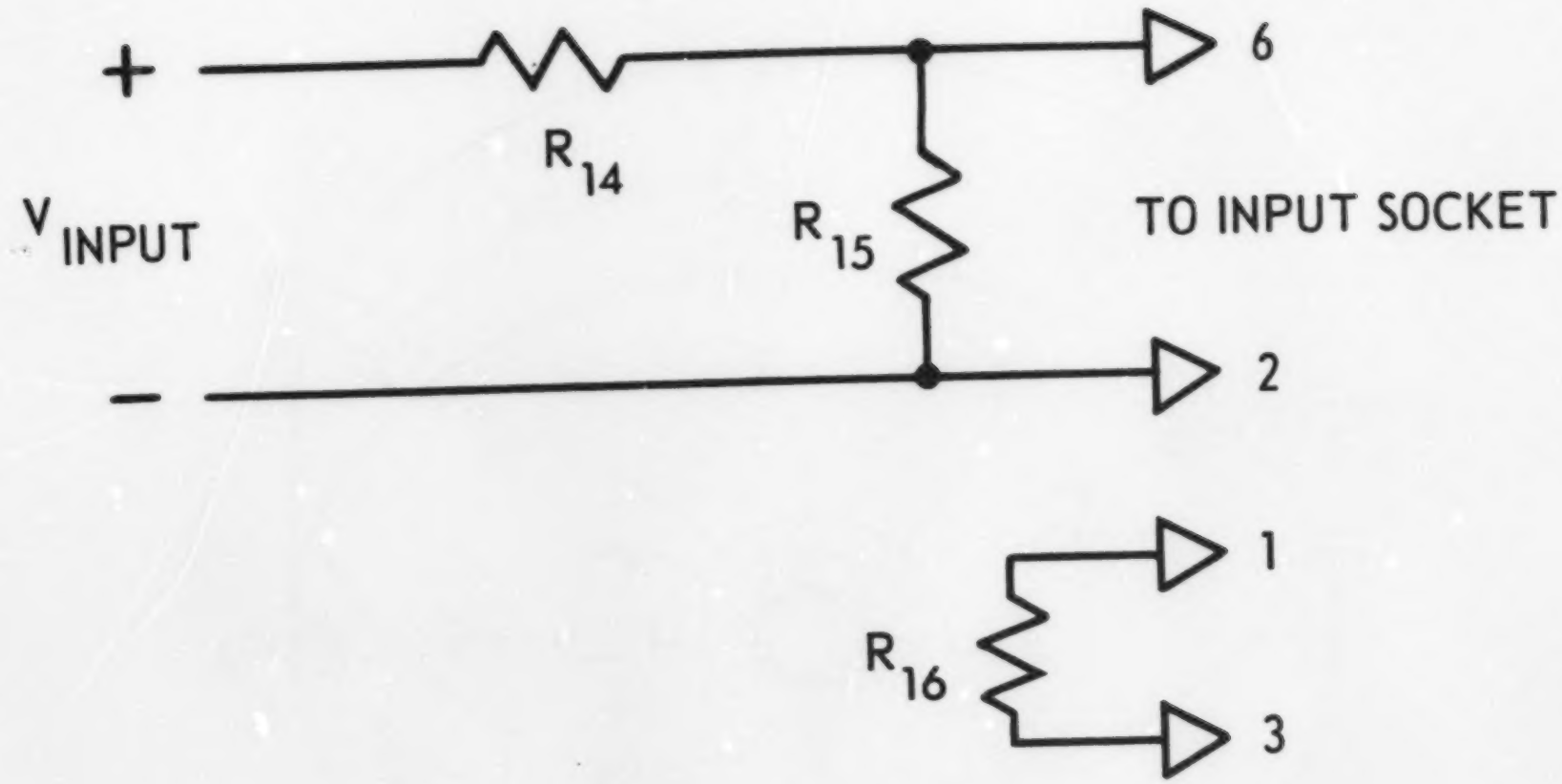


Figure 3 Schematic diagram of the test circuit

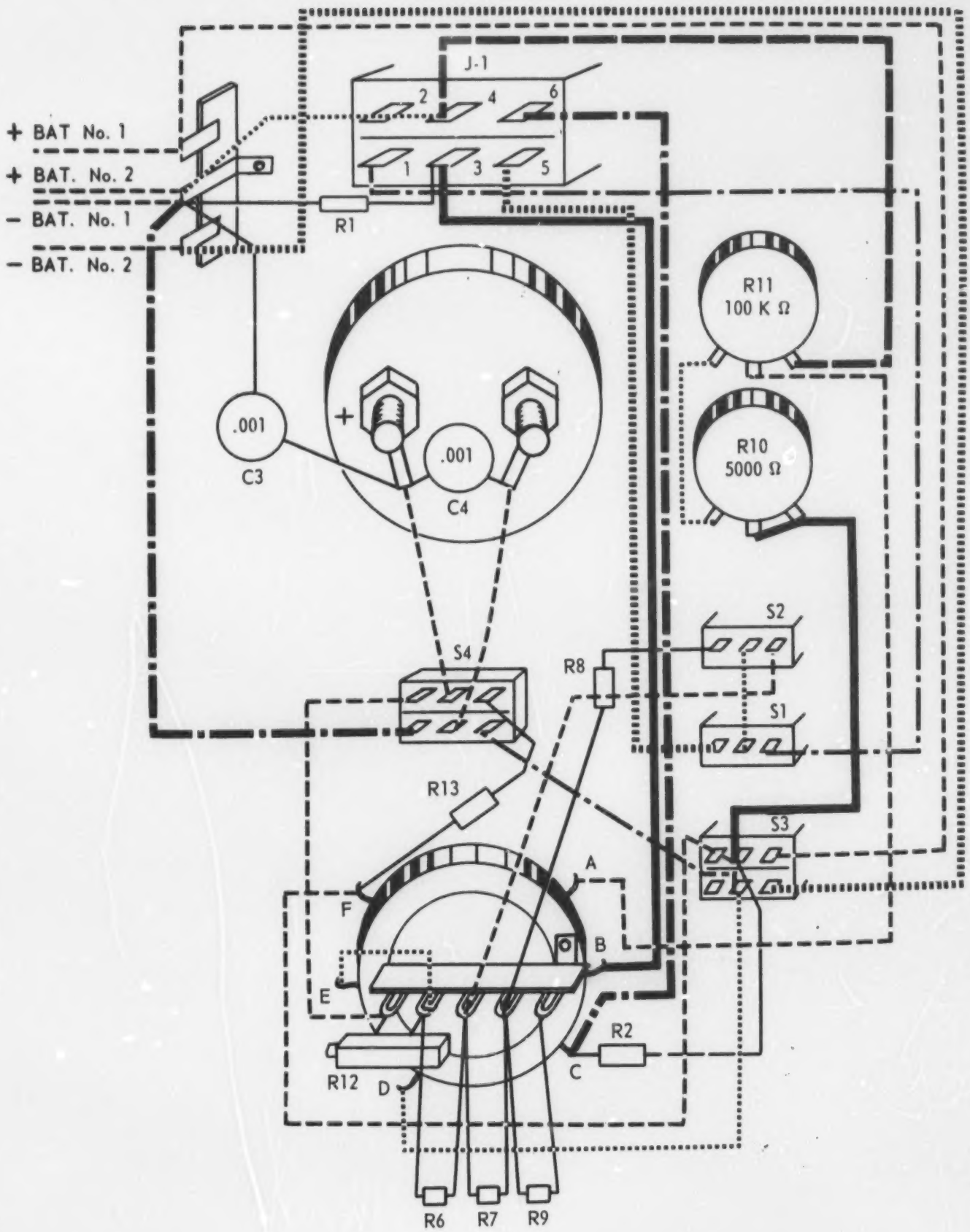


Figure 4 Pictorial drawing of the inexpensive readout for Narda 8122 probe.

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Robert L. Cloke
INEXPENSIVE READOUT FOR A COMMERCIAL THERMOCOUPLE MICROWAVE POWER DENSITY PROBE

Accession No.

U.S. Department of Health, Education, and Welfare, Public Health Service Publication Number BRH/DEP 70-31 (December 1970), 13 pp. (limited distribution).

ABSTRACT: This paper describes an inexpensive, easy-to-build readout circuit which can be used with the Narda 8122 thermocouple microwave power density probe. The instrument is capable of reading full-scale power densities of 10 mW/cm^2 and 100 mW/cm^2 at frequencies of 915 MHz and 2450 MHz, and includes

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KEYWORDS: Microwave leakage detection; Microwave oven; Microwave survey instrument; Power density measurement.

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DIVISION OF ELECTRONIC PRODUCTS

List of Publications

(continued from inside of front cover)

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BRH/DEP 70-13	Variability in the Automatic [illegible]cessing of Medical X-ray Film (June 1970) (PB 192 702)
BRH/DEP 70-14	Simple X-ray Detection Instruments for Television Service Technicians (June 1970) (PB 192 377)
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BRH/DEP 70-20	Investigation of the Response of the Microlite 287 Probe to Microwave Fields (August 1970) (PB 193 223)
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BRH/DEP 70-24	In-Plant Survey of Television Receivers for X-radiation Emission Capability (September 1970) (PB 194 316)
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BRH/DEP 70-26	Electronic Product Radiation and the Health Physicist - Health Physics Society Fourth Annual Midyear Topical Symposium (October 1970)
BRH/DEP 70-27	A Study of Head and Neck Exposure from Polytomography (November 1970) (PB 195 702)
BRH/DEP 70-28	Present Federal Control of Health Hazards from Electronic Products Radiation and Other Types of Ionizing Radiation (November 1970)
BRH/DEP 70-29	Electronic Product Inventory Study (November 1970)
BRH/DEP 70-30	A Study to Determine the Necessity for the Development of Standards for the Use of Selected Nonmedical Electronic Products for Commercial and Industrial Purposes (December 1970)
BRH/DEP 70-31	Inexpensive Readout for a Commercial Thermocouple Microwave Power Density Probe (December 1970)